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Effects of Timber Harvesting and Subsequent Re-Growth on Seasonal Soil Water Content, Soil Temperature and Evapotranspiration.

1999 – Final Report (Phase 1)

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By G.R. Hillman, C.C. Feng, P.A. Hurdle and G.W. Taylor
Canadian Forest Service – Natural Resources Canada
Northern Forestry Centre
Edmonton, Alberta
Canada

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Edmonton, Alberta

DISCLAIMER

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Introduction

The Canadian boreal forest is being subjected to a greater intensity of management activities than ever before. Consequently, there is a need to develop an understanding of the impacts of these activities on the forest, and to select suitable forestry practices to mitigate any adverse effects of these activities. Because this kind of information is generally lacking, particularly for the long term, the EMEND (Ecosystem Management by Emulating Natural Disturbance) project was established in 1997. Its purpose was to determine which harvesting and forest regeneration practices best maintain ecosystem structure and function in comparison with mixed-wood landscapes that have arisen from the current natural disturbance regime, and to assess the economic viability and sustainability, and social acceptability of these forestry practices (Volney *et al.* 1999). The study is expected to generate new knowledge over the next 100 years.

Soil water and soil temperature play an extremely important role in plant growth and, in turn, are markedly affected by changes in vegetation patterns. Ideally, these variables should be studied in conjunction with changes in vegetation patterns that occur as a result of timber-harvesting, fire, forest regeneration and succession. The EMEND project provides an opportunity to conduct such a study. Soil water content and soil temperature can be greatly affected by forest practices such as timber-harvesting. Clear-cutting in particular generally results in an increase in soil water content (producing flooded conditions on some sites), higher summer and lower winter soil temperatures, and a reduction in evapotranspiration (Donnelly *et al.* 1991, Kubin and Kemppainen 1991). Soil water content, soil temperature and evapotranpiration have all been measured in relation to the forest environment but their synthesis in relation to different forestry practices is limited and needs to be investigated.

Evapotranspiration (ET) is the process by which water moves through soil and plants on its way to the surface, from which it finally diffuses into the bulk air (Kramer 1969). In the western boreal forest it usually represents a considerable proportion of mean annual precipitation, and can be determined from water balance equations, or by using more complex, eddy correlation/energy balance relations.

Estimates of mean annual ET for the European boreal forest using simple water balance equations range from 169 mm in Siberia (Kelliher *et al.* 1997) to 430 mm in Finland (Seuna 1981), or 79% and 61% of mean annual precipitation, respectively. In the Canadian boreal forest (near Slave Lake, Alberta), Lieffers and Rothwell's (1986) estimated mean annual ET of 390 mm was 82% of mean annual precipitation. For the Canadian boreal forest as a whole, and for the EMEND site in particular, mean annual ET is about 445 and 350 mm, or 66 and 70% of mean annual precipitation, respectively (Fisheries and Environment Canada 1978). ET is being measured and evaluated on the EMEND site as part of the hydrology and other sub-studies to determine relationships between changes in the forest stand structure and ET; and to relate losses to the atmosphere through ET, to precipitation inputs and changes in soil water content, particularly during the growing season.

The objectives of the hydrology study are:

1. To determine the effects of different levels of timber harvesting and regrowth in coniferous stands on soil temperature and volumetric soil water content (including seasonal groundwater table levels where appropriate);

2. To establish the hydrological relationships between precipitation, soil water and evapotranspiration on treed and cutover areas.

3. To establish the relationships between plant variables (biodiverstiy of trees and shrubs; productivity; and forest regeneration survival) and seasonal soil water and temperature conditions.

The hydrology sub-study of the EMEND project was initiated in 1997 and established in a coniferous dominant stand (CDOM Stand 314, Rep 2) in 1998. The stand was designated CDOM as it contained > 70% white spruce (*Picea glauca* (Moench) Voss). Pre-harvest soils data for the stand were obtained from a network of dataloggers, soil water and temperature sensors installed in 5 compartments, each 8- to 10-ha in size. Meteorological data were obtained from instruments mounted on a 30-m tower located in the control compartment (Hillman *et al.*1998).

In winter 1998–99, five compartments were subjected to different levels of timber harvesting: 0 (clear-cut), 10, 20, 50, and 75% residual trees (Fig. 1). Post-harvest soil water and soil temperature data were collected from the five harvested compartments and the control compartment (100% residual trees) during the 1999 growing season. Meteorological data were obtained from the tower in the control compartment. This report describes the field work completed in 1999, outlines some of the results obtained and indicates future directions of the study. Further details regarding the hydrology study can be found in Hillman *et al.* (1998).

Description of the Experimental Area

A general description of the EMEND project area is provided in Hillman *et al.* (1998). The following description is specific to CDOM St. 314, rep 2, which is divided into east and west sections by a northward-flowing creek (Fig.1). The small creek is moderately to steeply incised, is bordered by slopes that drop 10 m to the floodplain and has a channel slope of 0.005. Compartment boundaries closest to the creek are located 50 to 500 m away from it. On the east side of the creek, the 10%, 20% and control (100%) compartments have a NW aspect. Compartments on the west side (0, 50, and 75%) are located on a domed upland, lie adjacent to wetlands and have an ESE aspect.

The surface topography of all compartments generally exhibits relief of about 10 m with moderate to complex micro-topography. All compartments have gentle to moderate slopes toward the creek, and, with the exception of the clear-cut, are located downslope from upland aspen/conifer forest. The clear-cut compartment is located downslope from an upland conifer forest and is probably also affected by water draining from an upslope, 5-ha wetland. Within the control, 20, 50 and 75% compartments, soil water and temperature sensors are located about 300 m from the creek. In the clear-cut and 10% compartments, the distances are 75 and 500 m, respectively. Thus the sensors are probably located on different topographic gradients within compartments.

The compartments are characterized by moderately to imperfectly drained Luvisols developed on glacio-lacustrian parent material. Surficial soils within different compartments have similar profiles (Tables 1 and 2), but depositional layering of soils to 0.5 m depth was observed, from dry/tight clays to non-cohesive medium and coarse sands.

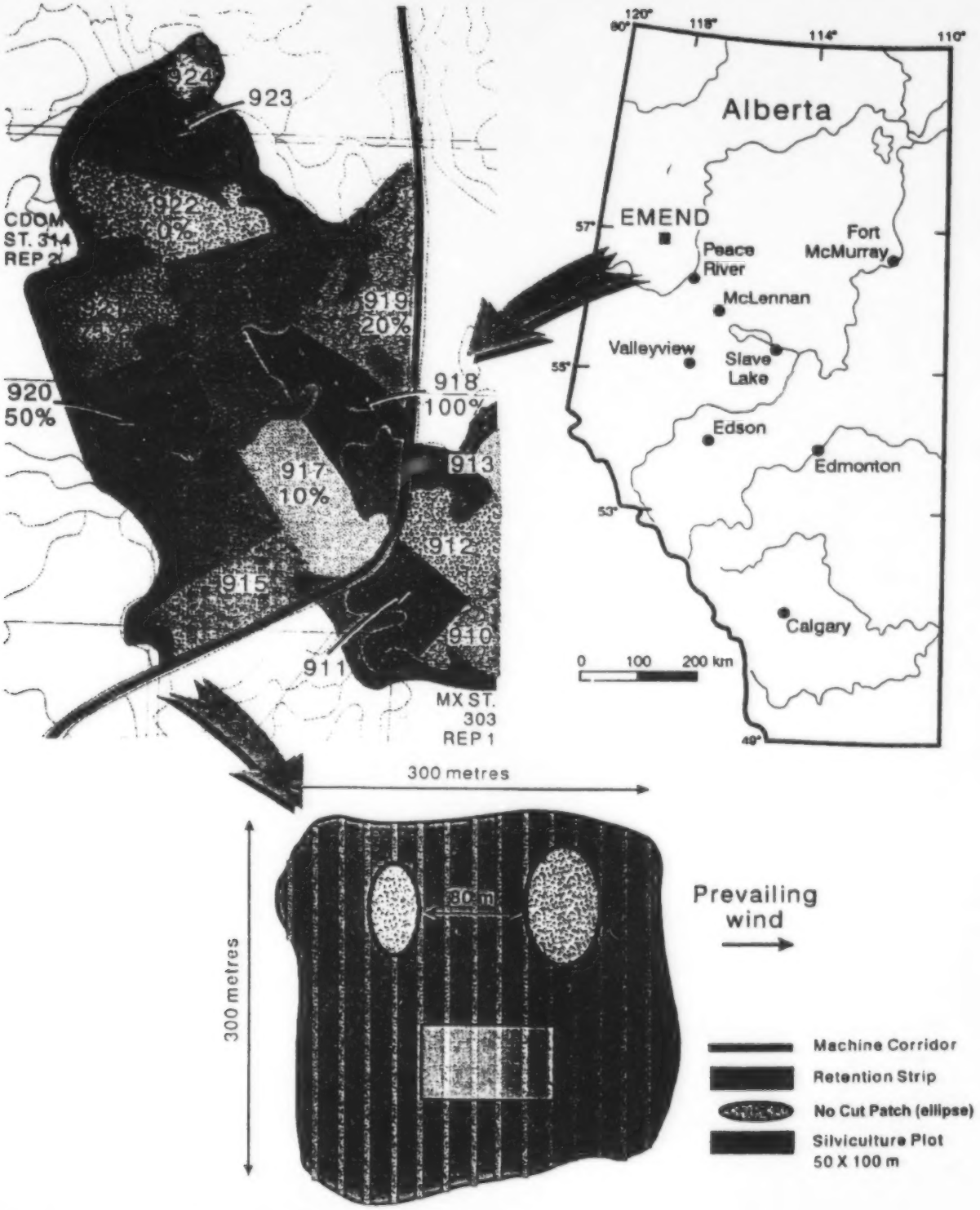

Figure 1. EMEND hydrology study: location, compartment layout and timber harvest pattern. The latter two maps were prepared and supplied by Derek Sidders, Canadian Forest Service.

Table 1. Description of soil profile located in compartment 918 (control site) of conifer-dominant stand 314, rep 2 (Provided by Ivor Edwards, Canadian Forest Service).

Horizon	Depth (cm)	Description
LFH	16 - 0	Very fibrous, not very well decomposed: abrupt, smooth boundary.
Ae	0 -15	Light brownish gray (2.5Y 6/2); abrupt wavy boundary, clayey texture; weak, fine, platy structure, slightly hard consistence (dry); faint mottling.
Bt1	15 - 30	Dark grayish brown (10YR 4/2); clear smooth boundary; clayey texture; moderate, fine, angular blocky structure, firm consistence (moist); faint mottling.
Bt2	30 - 40	Dark brown (7.5YR 4/2); gradual, smooth boundary; clayey texture; weak, fine, angular blocky structure; friable consistence (moist); few stones; faint mottling.
Bt3	40 - 58+	Dark gray (7.5YR 4/0); clayey texture, weak, fine, angular blocky structure; friable consistence (moist); iron oxide coating on peds (interior of peds very dark gray, exterior yellowish brown).

General comments: Faint mottling in Ae and Bt horizons indicates imperfect drainage. Moss layer dense, extensive.

Landform: Level
Drainage Class: Imperfectly drained
Ecosite: White spruce-viburnum; some mature aspen present among the white spruce.
Condition: Dry
Vegetation: twinflower, coltsfoot, peavine, bunchberry, rose, wintergreen, fireweed, grass, viburnum, buffaloberry, feathermoss, horsetail, birch, alder
Parent Material: Glacio-lacustrine
Soil Group: Luvisol

Table 2. Description of soil profile located in compartment 917 (10% residual) of conifer-dominant stand 314, rep 2 (Provided by Ivor Edwards, Canadian Forest Service).

Horizon	Depth (cm)	Description
LFH	15 - 0	Not very well decomposed, fibrous, peaty mor; abrupt, smooth boundary.
Ae	0 - 15	Reddish gray (2.5Y 6/2); clear, wavy boundary; loamy texture; weak, medium, platy structure; soft consistence (dry); no mottles.
Bt1	15 - 30	Grayish brown (10YR 5/2); gradual, wavy boundary; clayey texture; moderate, fine, angular blocky structure; firm consistence (moist); faint mottling, iron oxide coating on peds; few large stones.
Bt2	30 - 45	Dark grayish brown (10YR 4/2); gradual, wavy boundary; clayey texture; moderate, fine, angular blocky structure; firm consistence (moist); iron oxide coating on peds.
Bt3	45 - 60+	Dark gray (10YR 4/1); clayey texture; moderate, fine, angular blocky structure; firm consistence (moist); iron oxide coating on peds.

General Comment: Although moderately well drained (no mottling in Ae horizon), the rate of decomposition is slow as evidenced by the thick layer of fibrous material in the LFH. This indicates extended periods of cool, moist conditions below the white spruce canopy.

Landform: Level
Drainage class: Moderately well drained
Ecosite: White spruce-viburnum
Condition: Dry
Vegetation: feathermoss, bunchberry, rose, coltsfoot, twinflower, viburnum, showy aster, peavine, wintergreen, fireweed, grass, bedstraw
Parent material: Glacio-lacustrine
Soil Group: Luvisol

Methods

Instrumentation to monitor soil water and soil temperature at 2-hour intervals now exists in six compartments: control, clear-cut, 10, 20, 50 and 75% residual treed areas. Each setup, consisting of eight temperature and eight soil water sensors, provides a minimum of two replicates per treatment in each compartment (please refer to item 2. under **Progress in 1999**). To provide a better statistical measure of spatial variability additional measurements are obtained on a less frequent basis than 2-hourly intervals using portable sensors.

In 1998, thermistors were installed horizontally at four depths: at the soil surface, at the interface between the organic layer and the mineral soil, and at depths 15 cm and 30 cm below the top of the mineral soil. Soil water sensors were installed in the middle of the organic horizon, and at depths 15, 30, and 45 cm below the top of the mineral soil. The water sensors in the organic layer were placed

horizontally, and those in the mineral soil were installed via the surface at an angle of about 20° from the vertical. In the compartments designated as residual treed areas, one set of thermistors and water sensors was installed near the centre line of a machine corridor and the other within a residual treed area (Fig. 1).

To obtain a more complete understanding of the responses of hydrologic processes to change in vegetation composition and structure, data pertaining to evapotranspiration are essential. Different methods for measuring or estimating evapotranspiration will be assessed for possible application to this study.

Forests have an appreciable effect on groundwater, particularly when the water table is near the surface (Hewlett and Nutter 1969). A knowledge of local groundwater systems provides information on water sources other than direct precipitation, e.g., subsurface flow into compartments. It also indicates if soil water is being replenished from below. In the EMEND CDOM stand 314, the depth, direction and velocity of groundwater flow is being determined in each compartment using a system of one 5-cm dia. groundwater well located at the 3-m depth, and three to four 3.8-cm dia. piezometers inserted to depths between 1.8 and 5 metres.

The hydraulic conductivity of the porous media, which controls groundwater flow rate, is measured *in situ* using a standard Hvorslev bail or slug test method (Fetter 1980: Freeze and Cherry 1979) with piezometer construction and installation for a low permeability unit. In this method, water is bailed from the piezometer and monitored as the level recovers. Simple estimates of hydraulic conductivity are calculated using recovery data and Hvorslev's equation.

Progress in 1999

Unless indicated otherwise, the following activities were completed in the coniferous dominant stand (CDOM ST. 314 REP 2) :

1) In winter 1998–99, five 8- to 10-ha compartments were subjected to different levels of timber harvesting: 0 (clear-cut), 10, 20, 50, and 75% residual trees (Fig. 1). One other compartment (100% residual) was not disturbed and will serve as an experimental control. All harvested compartments, except the clear-cut, have certain common features: 15-m-wide treed strips, 5-m-wide machine corridors and 2 uncut elliptical patches of 0.20 and 0.46 ha—a basic pattern that also defines the 75% residual treatment when no trees are harvested from the treed strips. Increasing numbers of trees were removed from the 15-m-wide residual treed strips to obtain the other levels of timber harvest, e.g., 1 of every 3 trees for the 50% residual, 3 of every 4 trees for the 20% residual, and 7 of every 8 trees for the 10% residual stand. All trees in the clear-cut compartment except those in the ellipses were felled. Winter soil temperature data were collected in the control and 75% residual compartments.

2) Dataloggers, soil water and soil temperature instrumentation were re-established in the cut and treed portions of four timber-harvested (i.e., 20, 50, 75% residual, and clear-cut) compartments and one control compartment. Similar instrumentation was installed for the first time in the 10% residual compartment, but no instrumentation was installed in the medium burn compartment because of the

uncertainty associated with the time of burning. Soil water and soil temperature were monitored in all six compartments during the 1999 (first post-harvest) growing season. The distribution of the sensors and the number of replicates in each compartment are shown in Table 3.

Table 3. Distribution of soil temperature and soil water sensors in six compartments of the coniferous dominant stand.

Compartment	No. of replicates		Soil temperature				Soil water			
	Cut/ MC[a]	Treed strips	Surface	Interface[b]	Depth in mineral soil (cm)		Organic layer	Depth in mineral soil (cm)		
					15	30		15	30	45
Clear-cut	1	-	x	x	x	x	x	x	x	x
Control	-	1	x	x	x	x	x	x	x	x
Clear-cut	2	-	x	-	x	-	-	x	x	-
Control	-	2	x	-	x	-	-	x	x	-
10[c], 20, 50, 75%	2	2	x	-	x	-	-	x	x	-

[a] MC = Machine Corridors.

[b] Interface between the organic layer and the mineral soil.

[c] Two machine corridor replicates and two treed replicates in each partial-cut compartment.

3) Below-canopy photosynthetically active radiation, air temperature and relative humidity sensors were installed at seedling (20-cm) height in four (0, 50, 75, and 100% residual) compartments of the CDOM stand. Similar installations were completed in the corresponding compartments and the 20% residual compartment of ADOM stand 77, rep.1 (> 70% aspen (*Populus tremuloides* Michx.)). An energy balance determination of evapotranspiration was completed in the ADOM clear-cut compartment by B. Amiro, Canadian Forest Service.

4) In each of the five harvested compartments and the control, established three to five transects to facilitate periodic (spot check) sampling of soil water and soil temperature (Fig. 2). Comparison of 2-hourly recorded logger data with transect data for hillslope and topographic gradients, will address spatial variability within each compartment. Spot check sampling was also conducted within the range of sensor distribution (25-m radius) to examine spatial variability at the micro-scale. Four sets of microsite spot check data were collected in summer, 1999.

5) Used GPS technology to determine the locations of baselines, transects and dataloggers in all six compartments. Recorded bearings and measured distances of sensors relative to the dataloggers in all compartments for microscale analysis.

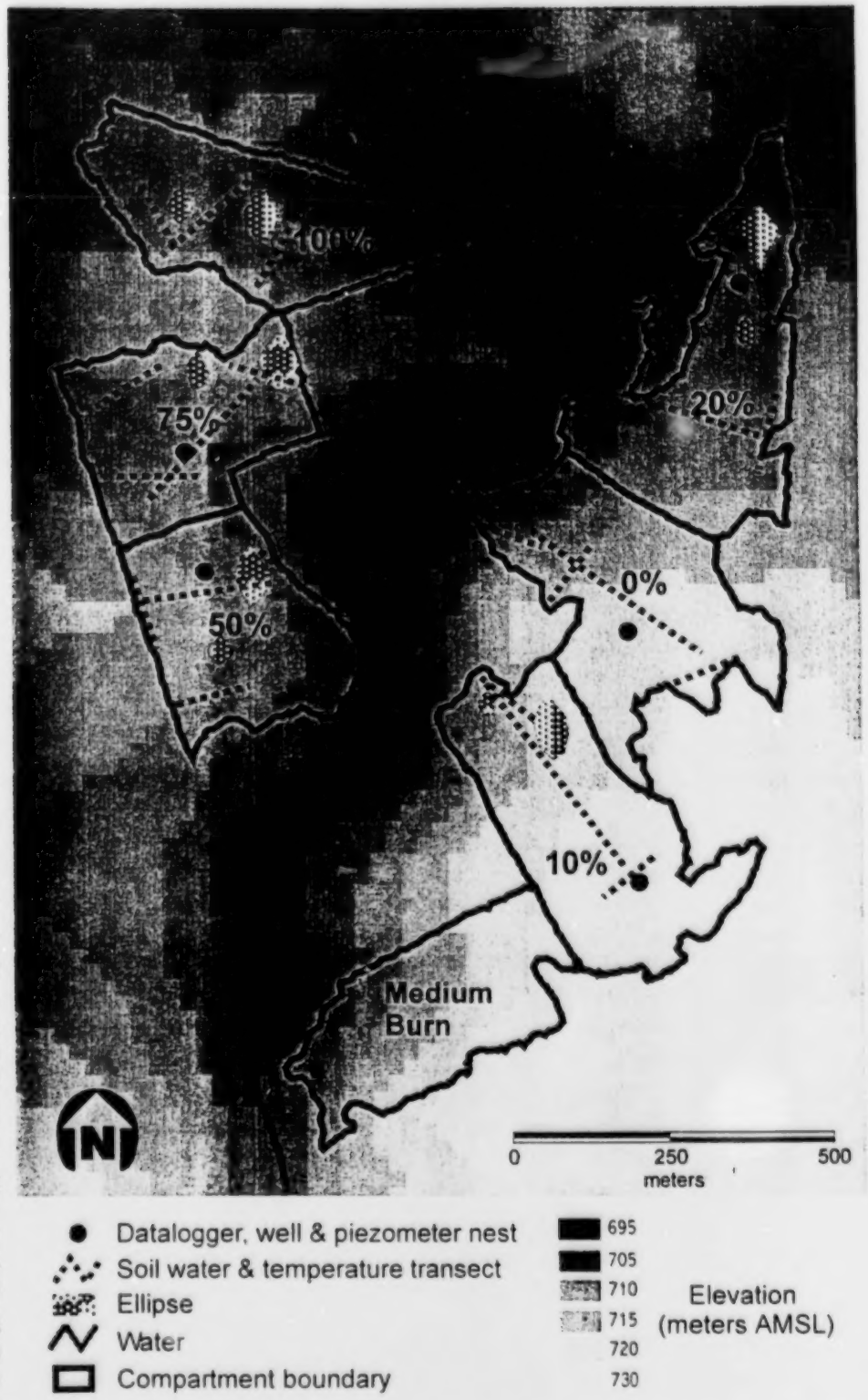

Figure 2: Map of conifer-dominant study site showing topography, location of instrumentation and associated transects.

6) Calibrated soil water and temperature sensors by comparing in-situ measurements with standard laboratory analysis (i.e., oven-dry determination of soil water, and using temperature baths).

7) Conducted topographic surveys in seven compartments. In each compartment, established spot check transects 100 to 380 m long and determined tree species composition and crown closure at 20-m intervals.

8) Installed a 5-cm dia. groundwater well to 3-m depth and a piezometer nest consisting of three to four piezometers, each 3.8 cm in diameter, inserted to depths between 1.8 metres and 5 metres at each instrumented site (Fig. 2). Measured hydraulic head and hydraulic conductivity in each system and obtained soil profile descriptions from the soil cores.

9) In October, 1999 at the *Forest Explorer's* conference held in Manning, demonstrated soil water and soil temperature measuring equipment, and presented posters related to the EMEND hydrology study.

Preliminary Results

The purpose of this section is to present some general trends in soil water and soil temperature response to timber harvesting rather than to provide a comprehensive data analysis and interpretation.

Coniferous dominant stand - soil temperature

Prior to timber harvest(1998), the maximum, minimum, and mean daily temperatures at four points in the soil profile were markedly similar in the five compartments where temperatures were measured (Table 4). After harvest (1999), higher maximum temperatures were recorded at the soil surface and at depth on sites where more than 50% of the trees were removed. In the more extensively cut compartments, maximum surface temperatures were 9–10°C higher than before harvest. Below-surface temperatures on the clear-cut were about 3°C higher than before harvest.

Mean daily soil temperatures for the two periods were not noticeably different at either the surface or at depth (Table 4), although on the clear-cut compartment, subsurface temperatures tended to be 2–3°C warmer in 1999 than in 1998. Before harvest, minimum soil surface temperatures were roughly the same in all compartments. After harvest, minimum surface temperatures tended to decrease with increasing percentage of trees removed. Temperature differences between pre- and post-harvest periods tended to diminish with depth.

Overall, the data indicate that removing more than 50% of the trees from the coniferous dominant stand leads to greater extremes of temperature at the soil surface. Thus, the surface temperature range on the 20% residual treed compartment in 1999 was 12°C greater than in 1998. Removing a significant portion of the forest canopy evidently exposes the site to greater solar radiation by day and to greater heat loss by night.

Table 4. Maximum, mean and minimum daily temperatures (°C) at four points in the soil profile in the coniferous dominant stand for the pre-harvest period (August 25 to October 6, 1998) and the corresponding post-harvest period (August 25 to October 6, 1999). For the partial-cut compartments (10, 20, 50 and 75%), data from sensors in the machine corridors and the treed strips were combined.

Residual trees (%)	Air temperature						Mineral soil			
	Met. tower		Surface		Interface[a]		15-cm depth		30-cm depth	
	1998	1999	1998	1999	1998	1999	1998	1999	1998	1999
Maximum:										
100 (control)	25.4	25.4	21	19.6	11.1	9.1	9.4	9.3	8.8	8.3
75	-	-	21.4	21.9	10	-	8.8	9.9	8.4	-
50	-	-	23.2	26.1	10.3	-	9.4	10.6	8.9	-
20	-	-	26.1	35.9	9.8	-	8.7	10.2	8.2	-
10	-	-	-	32.4	-	-	-	11.2	-	-
0 (clear-cut)	-	-	22.7	31.4	10.1	12.8	8.4	11.7.	8	11.4
Mean:										
100	9.1	7.8	8	7.6	7.6	7.4	7.5	7.6	7.4	7.3
75	-	-	7.9	7.9	7.4	-	7.2	8	7.2	-
50	-	-	8.1	8.1	7.5	-	7.4	8.5	7.3	-
20	-	-	8.2	8.4	7.3	-	7.2	8.3	7	-
10	-	-	-	8.6	-	-	-	9	-	-
0	-	-	8.2	8.9	7.2	9.5	6.9	9.4	6.8	9.4
Minimum:										
100	-3.8	-8.2	-0.3	-1.4	4.7	4.9	5.5	5	5.7	5.5
75	-	-	-1.5	-1.3	4.7	-	5.3	5.1	5.6	-
50	-	-	-1.2	-2.3	4.6	-	5.6	5.6	5.7	-
20	-	-	-1.5	-3.6	4.8	-	5.3	5.7	5.6	-
10	-	-	-	-4.4	-	-	-	6.2	-	-
0	-	-	-2.5	-3.8	4.8	5.5	5	6.2	5.5	6.7

[a] Interface between the organic layer and the mineral soil.

A comparison of soil temperature data for a single site in the clear-cut compartment before and after harvest (Fig. 3) shows there was a significant increase in the range of soil surface temperature after harvest—to about 50°C compared with 26°C before harvest. Subsurface temperatures were slightly warmer after harvest and tended to decrease with depth during the growing seasons of both years. The difference in temperatures between the organic/mineral soil interface and the 30-cm depth, however, rarely exceeded 2 or 3°C. In the fall, temperatures were generally lower at the interface than in the lower soil horizons. The data also illustrate the effects of cloud and precipitation, i.e., a noticeable drop in surface temperature occurred during these events (Fig. 3b).

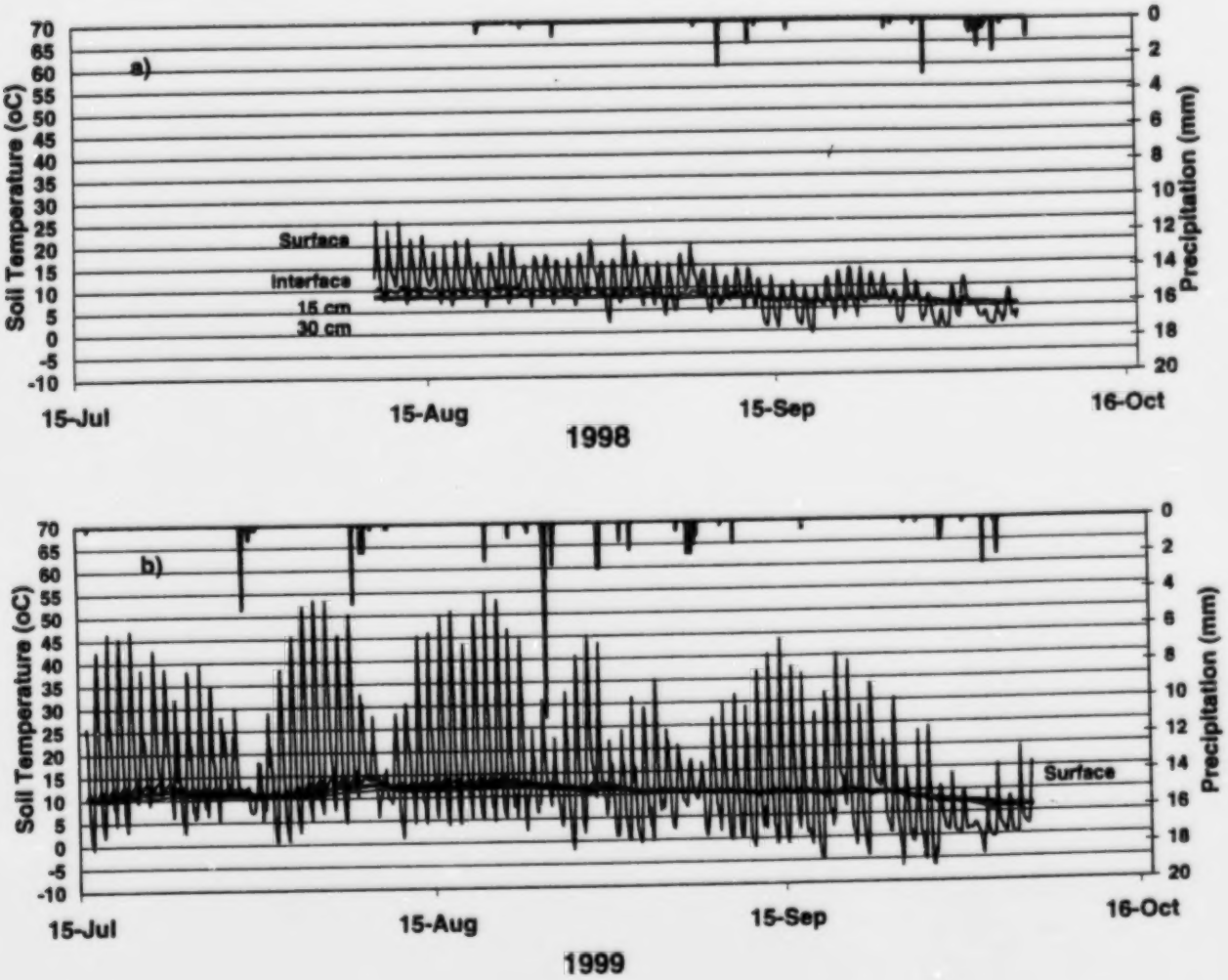

Figure 3. Soil temperature at the surface and at three depths in compartment 922 a) before, and b) after, clear-cut timber harvest. Precipitation is shown as vertical bars.

Surface temperatures and temperatures at the 15-cm depth in the 75% residual compartment after harvest were similar to, and slightly higher than those in the control compartment (Fig. 4). Temperatures in the machine corridor were practically the same as corresponding temperatures in the treed strip (Figs. 4b and 4c). This is to be expected as the canopy was opened only slightly, the 5-m-wide machine corridors allowing only a small amount of light and energy to penetrate to the floor of the machine corridors and the edges of the adjacent undisturbed treed strips. The high latitude of the EMEND study location, where the sun is overhead for only a small portion of the year, also limits the amount of radiation reaching the floor of the machine corridors in the 75% residual.

When the canopy was opened up to 50% residual by extracting trees from the treed strips (compartment 920, Fig.1), there was a further increase in surface temperatures on both the treed strip and the machine corridor (Figs. 4 and 5). Temperatures at the surface and the 15-cm depth in the machine corridor were slightly higher than those in the treed strip (Fig. 5). Surface temperatures for the treed strips and the machine corridors in the 10 and 20% residual compartments (not shown) tended to be intermediate between those of the 50% residual (Fig. 5) and the clear-cut (Fig. 3).

Coniferous dominant stand - soil water

Voltage outputs obtained from the soil water sensors in 1998 and 1999 were converted to percent volumetric water content using factory calibrations—one for the organic horizon and another for mineral soil—resident in the dataloggers. These data, therefore, are subject to verification through further laboratory and *in situ* field calibration. Verification and calibration checks are projected to be ongoing.

Maximum volumetric water content in the organic layer of the control compartment was less in 1999 than in 1998 (Table 5). The mean and minimum water contents in the organic soil were slightly higher in 1999. In the mineral soil of the control compartment, differences in water content were small. Greatest differences in the maximum, mean and minimum water contents between the two years occurred in the organic horizon of the clear-cut with 1999 values being 25–26% greater than those of 1998. Noticeable differences were also observed at the 15-cm depth in mineral soil of the clear-cut where volumetric water content was 13 to 21% greater in 1999 than in 1998.

Although soil water content on the clear-cut compartment was noticeably higher in 1999 than in 1998 (Table 5), the water content in the organic layer, the 15- and the 45-cm depths changed very little during 1999 (i.e., the maximum, mean and minimum values for the clear-cut are similar). By contrast, the maximum recorded at the 30-cm depth in 1999 was the highest recorded on any compartment. It is not clear why water content at this particular depth on the clear-cut was so high—it may be related to the topographic position of one of the sensors which is located in a wet depression and the greater amount of precipitation (73.2 vs. 33 mm) that fell during the 1999 measuring period. In the partial-cut compartments (20, 50 and 75%), the maximum, mean and minimum volumetric water contents in mineral soil were consistently higher in 1999 than in 1998 (Table 5). The increase in water content observed in 1999 may be attributed, in part, to the greater amount of precipitation in 1999.

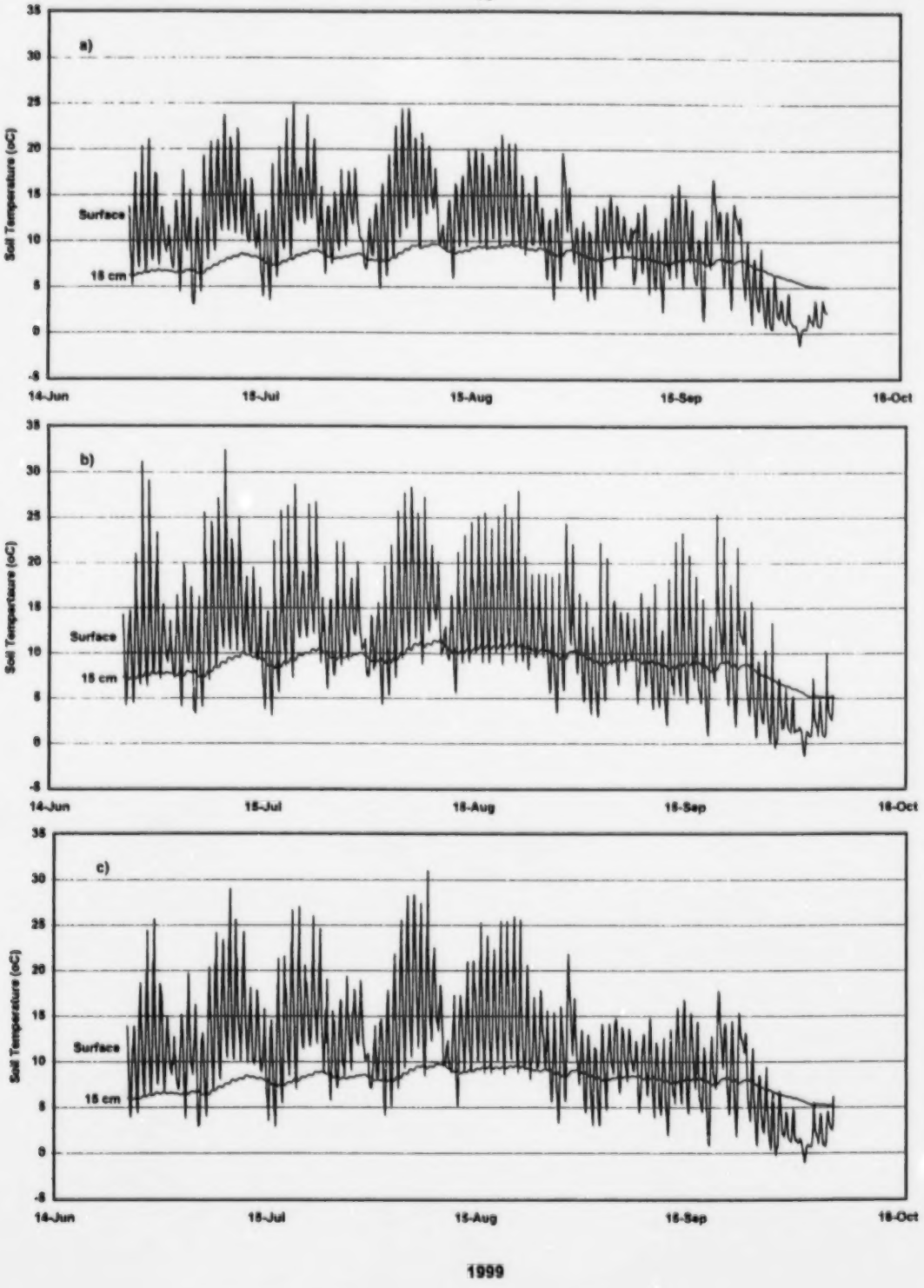

Figure 4. Soil temperature at the surface and 15-cm depth in a) the control compartment, b) a treed strip in the 75% residual compartment, and c) a machine corridor in the 75% residual compartment.

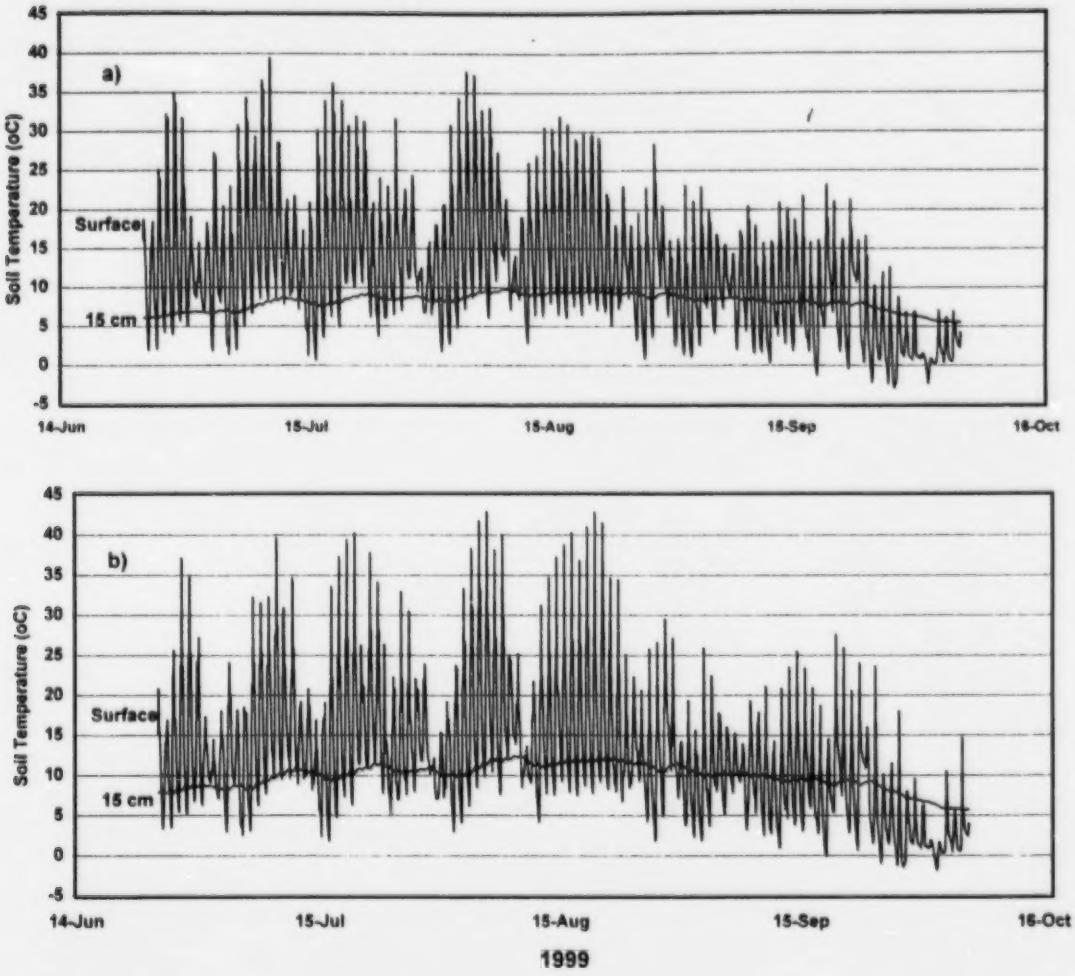

Figure 5. Soil temperature at the surface and the 15-cm depth in a) a treed strip in the 50% residual compartment, and b) a machine corridor in the 50% residual compartment.

Table 5. Maximum, mean and minimum daily volumetric water content (%) at four points in the soil profile in the coniferous dominant stand for the pre-harvest period (August 25 to October 6, 1998) and the corresponding post-harvest period (August 25 to October 6, 1999). For the partial-cut compartments (10, 20, 50 and 75%), data from sensors in the machine corridors and the treed strips were combined.

Residual trees (%)	Organic layer		Mineral soil					
			15-cm depth		30-cm depth		45-cm depth	
	1998	1999	1998	1999	1998	1999	1998	1999
Maximum:								
100 (control)	29	18	32	31	32	36	36	31
75	3	-	27	34	28	39	32	-
50	24	-	29	33	34	40	41	-
20	5	-	33	37	38	40	38	-
10	-	-	-	34	-	38	-	-
0 (clear-cut)	2	28	27	40	44	58	40	44
Mean:								
100	7	12	27	27	29	33	33	29
75	1	-	18	33	27	38	28	-
50	4	-	23	32	29	39	35	-
20	3	-	23	34	31	39	34	-
10	-	-	-	33	-	37	-	-
0	2	27	23	39	38	40	35	43
Minimum:								
100	2	8	26	27	26	31	30	29
75	1	-	6	31	27	37	27	-
50	1	-	20	31	28	37	34	-
20	1	-	19	33	26	38	32	-
10	-	-	-	32	-	36	-	-
0	1	27	16	37	34	37	32	41

After harvest in the partial-cut compartments, soil water contents at the 15- and 30-cm depths generally ranged between 30 and 40% (Figs. 6 and 7). Only at the 30-cm depth within machine corridors in the 20% residual compartment did water content consistently exceed 40% (Fig. 7a). Usually water contents at the 15-cm depth in the treed strips was slightly higher than at the same depth in the machine corridors. The exception was the 75% residual (Fig. 6a) where water contents in the treed strips at the 15-cm depth were about 7–8% higher than in the machine corridors. At the 30-cm depth, water content in the treed strips and the machine corridors were similar for 3 of the 4 partial-cut treatments (Figs. 6 and 7). At the 30-cm depth in the 20% residual compartment, however, water contents in the treed strips were about 5% greater than in the machine corridors (Fig. 7a).

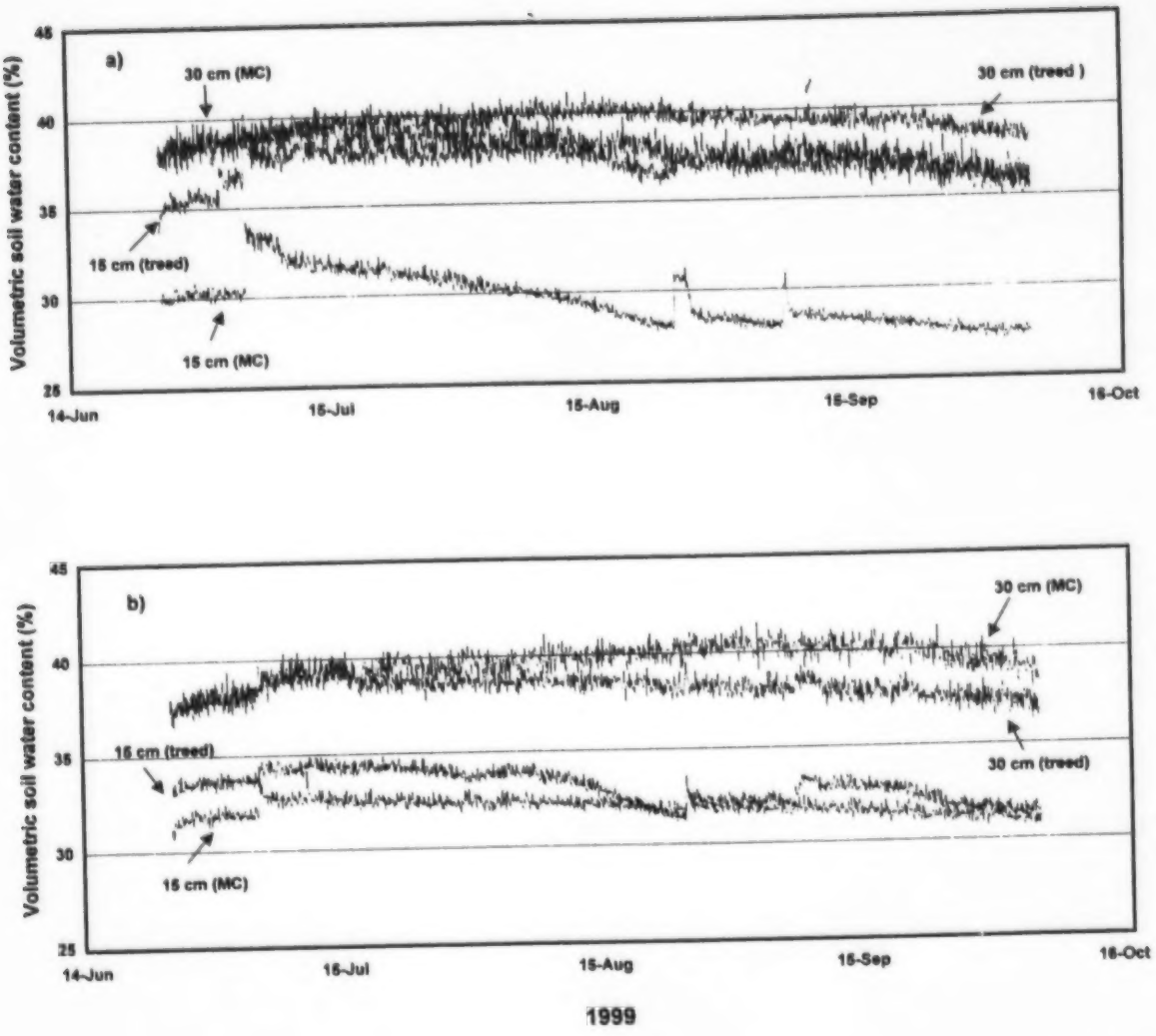

Figure 6. Mean volumetric water contents at the 15- and 30-cm depths in treed strips and machine corridors in a) the 75% residual treed compartment, and b) the 50% residual treed compartment. (MC) = machine corridor.

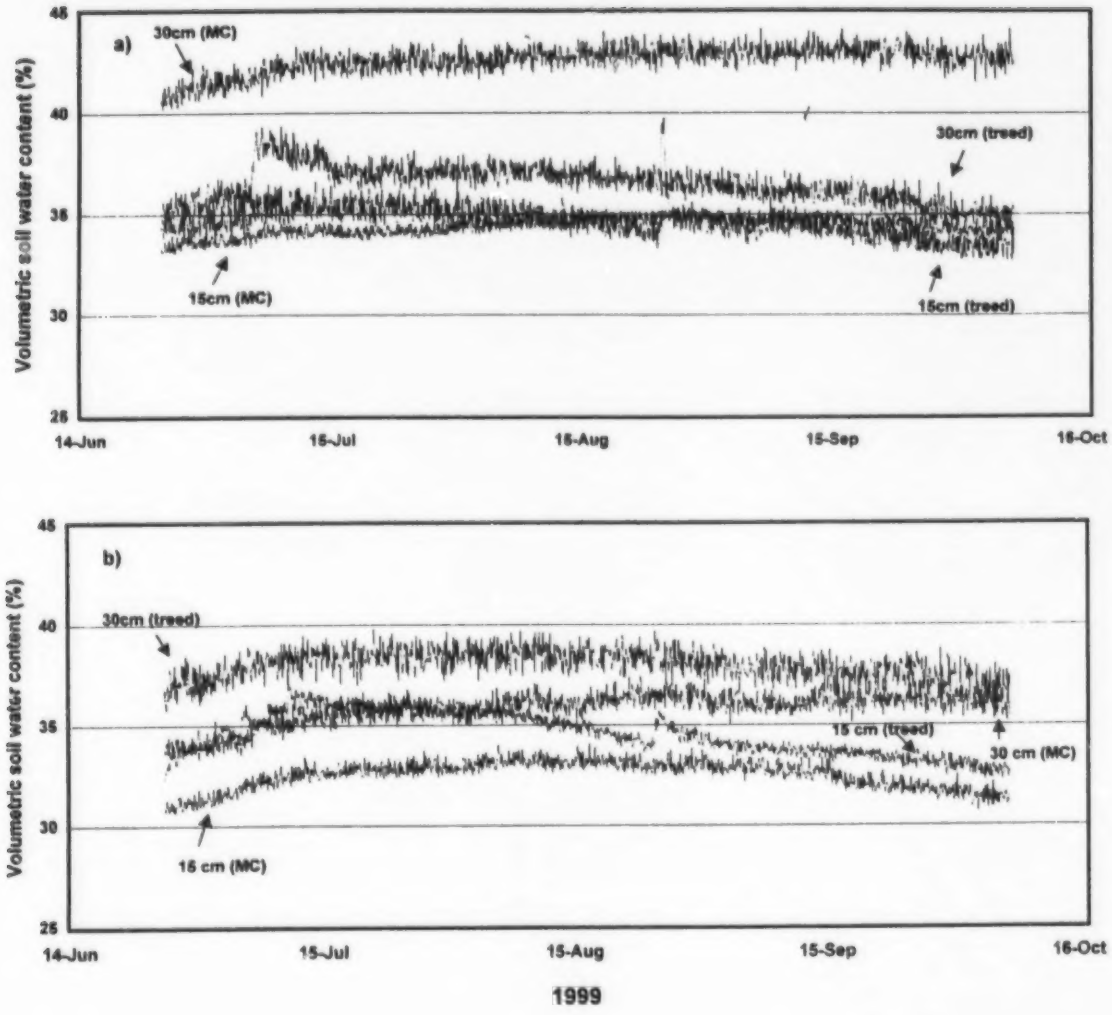

Figure 7. Mean volumetric water contents at the 15- and 30-cm depths in treed strips and machine corridors in a) the 20% residual treed compartment, and b) the 10% residual treed compartment. (MC)= machine corridor

Future Investigations and Work Plans

1. Improve the level of replication for soil water and soil temperature sampling in all compartments within the CDOM stand, particularly those with the greatest stand structural variability, e.g., 10, 20, and 50% residual.

2. Expand the range of piezometer nests so that upslope and downslope measurements of groundwater flow may be obtained in each compartment. Establish groundwater wells and piezometer nests in the ADOM stand.

3. Establish relationships and linkages between precipitation, changes in soil water content, groundwater levels, seasonal meteorological trends and evapotranspiration.

4. Establish a snow hydrology–forest regeneration study.

5. Develop an integrated soil water/ soil temperature hydrologic model (long-term).

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